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INFORMATION CIRCULAR

THE STORAGE OF COAL

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POINTERS ON THE STORAGE OF COAL

BY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

THE STORAGE OF COAL[1]

By J. F. Barkley[2]

INTRODUCTION

During the present war emergency, under the urge of the Federal Government to store coal, the following questions are frequently asked by coal users:

(a) Will the coal lose any of its heating value in storage?

(b) Will it slack and give a smaller-size coal?

(c) Will its burning characteristics change in any way?

(d) Will it catch fire from spontaneous combustion?

(e) What precautions should be taken when coal is stored?

DISCUSSION

(a) Loss of Heating Value

Studies by the Bureau of Mines show that the loss of heating value of coal in storage commonly has been overestimated. Various types of storage tests were made on New River, Pocahontas, Pittsburgh gas, and Sheridan (Wyo.) coals. The following is quoted from Bureau of Mines Bulletin 136, Deterioration in the Heating Value of Coal During Storage, by H. C. Porter and F. K. Ovitz (p. 8):

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[1] Revision and expansion of Bureau of Mines I.C. 7211, Pointers on the Storage of Coal. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7235."

[2] Chief, Division of Solid Fuels Utilization for War, Bureau of Mines, U. S. Department of the Interior.

Except for the subbituminous Wyoming coal, no loss in heating value was observed in outdoor weathering greater than 1.2 percent in the first year or 2.1 percent in 2 years. The Wyoming coal suffered somewhat more loss, 2 to 3 percent in the first year, and as much as 5.5 percent in 3 years.

These figures refer to the heating value of the coal substance itself, free from moisture and ash. If the heating value of 1 pound of the coal as piled is to be considered, the value would vary with any changes in moisture content; it is also slightly affected by small changes in the weight of the coal, owing to absorption of oxygen and giving off of gases. The coal may actually gain slightly in weight. The heating value is considerably affected if there is actual firing of the coal in storage. M. K. Drewry reports[3] an average yearly heat loss of 0.1 percent for five fireproofed piles stored, on the average, about 14 months and an average yearly loss of 0.9 percent for five unfireproofed piles stored, on the average, 4-1/2 months. By "fireproofing" is meant covering the pile with a material such as asphalt or coal dust to cut down the air flow through the pile. These figures of loss are on the basis of total B.t.u. lost from the pile as a whole and include some losses from coal fines carried away by the wind and from spontaneous heating in spots. The coal stored was a low-moisture coal of about 35 percent volatile matter.

(b) Slacking in Storage

The extent of slacking of coal in storage depends principally on the rank of the coal. The lower-rank coals, such as lignite, subbituminous coals, and high-volatile, high-inherent-moisture bituminous coals, slack from weathering much more readily than the higher-rank coals. The slacking, under good storage conditions, ordinarily extends only a short distance into the coal from any exposed surface. Very little difficulty, if any, from slacking should be experienced with the higher-ranking eastern coals. The Bureau of Mines has developed a laboratory test to indicate the tendency of a coal to slack.[4] Studies of these tests showed a wide variation in this tendency, as the "slacking indexes" ranged from about zero for some bituminous coals to nearly 100 for a Texas lignite. For coals having a natural bed moisture up to about 7 percent, the slacking was small; above this value, the slacking was more erratic, and in general increased appreciably with the bed moisture content.

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[3] Drewry, M. K., Storing Coal Safely: Power Plant Engineering, July 1942, pp. 65-68.

[4] Fieldner, A. C., Selvig, W. A., and Frederic, W. H., Accelerated Laboratory Test for Determination of Slacking Characteristics of Coal: Bureau of Mines Rept. of Investigations 3055, 1930, 24 pp.

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(c) Changes in Characteristics

Changes in burning characteristics may occur in some coals in storage. Such changes are important primarily for slack-size coals. For example, the caking tendencies of the coal may decrease appreciably. Whether or not the decrease in caking or coking tendencies affects the efficiency of the fuel-burning equipment depends on its type. For example, such a coal would not burn nearly as satisfactorily on a hand-fired, down-draft furnace; after being stored for many months it would not stay on the upper grates as well. Storage might improve the coal for use on domestic underfeed stokers or chain-grate stokers; for spreader stokers it would make little difference; for large underfeed stokers the efficiency might be affected. Sometimes coal, particularly low-volatile slack, acts "dead" after long storage, as described by a fireman; that is, it does not seem to ignite so readily at the lower temperatures. This tendency is noticeable chiefly in hand-firing, where furnace temperatures are not particularly high. Storage often greatly affects the coke-making properties of a coal.[5] Such effects are reported to appear within a week for some coals; other coals may not be affected appreciably for several years. There also may be slight changes in the mineral matter of the coal, which oxidizes to some extent. Such changes need not ordinarily be given much consideration.

(d) Spontaneous Combustion

Whether or not under given storage conditions a given coal will heat from spontaneous combustion to any undesirable extent depends on many factors. These factors include (1) the tendency of that particular coal to take up oxygen, a tendency that decreases as the oxygen is absorbed; (2) the temperature at which the coal is piled; (3) the fineness of any pyrite present; (4) the original size of the coal in the pile; (5) the tendency of the coal to slack; (6) the moisture conditions; (7) the amount of air available to the coal permitted by the conditions of ventilation throughout the storage pile; (8) the presence of foreign substances, such as wood, straw, and refuse; (9) the possibilities of dissipating any heat developed; and (10) any added heat from external sources. Owing to the complexity of these factors, exactly when and how much the coal will heat cannot always be judged for every storage condition. It is not difficult to store coal satisfactorily, provided these factors are evaluated correctly and the means are at hand for carrying out the proper methods needed for each case.

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[5] Schmidt, L. D. (Associate chemist, Bureau of Mines), Effects of Storage and Oxidation of Coal upon Coking Properties: Iron and Steel Engineer, March 1941.

(1) Spontaneous heating is caused by the uniting of the coal with oxygen; it is the same as the burning process in the furnace, except that it proceeds at a much lower rate. The following is quoted from Bureau of Mines Technical Paper 409 (p.64)[6]

> Oxidation of the coal substance itself is the main cause of spontaneous combustion; some of the organic constituents may contribute more to the heating than others, but it has not been shown that any one constituent exerts a preponderant influence to the exclusion of the rest.
>
> The process of spontaneous heating is operative at room temperatures as soon as freshly broken coal is exposed to the air. It begins with the physical absorption of oxygen and is continued by the formation of a solid chemical compound of coal and oxygen, which is gradually decomposed as the temperature rises. The coal increases in weight by the amount of oxygen retained. There follows the breaking up of the solid compound of coal and oxygen and the formation of the final oxidation products - carbon dioxide, carbon monoxide, and water. This process generates heat.

Coals vary a great deal in their natural or characteristic tendency to take up oxygen. In general, it is relatively low for high-rank coals. It is extremely low for anthracite. It is higher for coals of high bed moisture content, high oxygen content, and high volatile content, all of which characterize the low-rank coals. Schmidt reports[7] that a High Splint Kentucky coal under identical conditions consumed oxygen three times as fast as a Pocahontas No. 3 West Virginia coal.

(2) Technical Paper 409 may again be cited (p.64):

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[6] Davis, J. D., and Reynolds, D. A., Spontaneous Heating of Coal: Bureau of Mines Tech. Paper 409, 1928, 74 pp.

[7] Work cited in footnote 5, p. 3.

> With the Appalachian coals, oxidation begins to be appreciable at about 85° F. and increases in intensity as the temperature rises. With lower-rank coals the beginning temperature is lower. No coal has as an inherent property a critical temperature at which there is a sharp transition from relatively slow to rapid heating.

The reaction between coal and oxygen is considered to double for about each 15° F. If the temperature of the coal is 60° F. and it is raised to 90° F., the rate at which the oxygen unites with the coal increases four times.

(3) According to Technical Paper 409 (p.65):

> Pyrite when finely divided can increase the tendency of a coal to heat spontaneously. Although it has been shown that coals containing virtually no pyrite have fired spontaneously, it has also been quite definitely shown that fine pyrite, when present in the coal, does increase the rate of oxidation.

Pyrite is a compound of iron and sulfur. In general, the sulfur content of coal is largely in the pyrite compound. Pyrite unites with oxygen and water to form sulfuric acid and iron sulfate, giving off considerable heat in the process. Coal users who store coal under the various conditions found in industry in general are cautious about storing high-sulfur coals. Rains or water-flooding of coal may increase the rate of oxidation of the pyrite by supplying needed water or by washing off any products of oxidation formed on it. Pyrite is also accused of disintegrating the coal by its oxidation to bulkier products.

(4) An important factor in the heating process is the total surface area of the coal exposed to the air; the greater the surface the more chance of union with oxygen. Table 1 shows the variation of surface area with size. For 1 ton of coal in the form of a solid cube, there is about 48 square feet of surface; as the cube is broken down to smaller sizes, say to slack coal, there may be 20,000 or 30,000 square feet. Experience indicates that good-size egg or lump bituminous coal ordinarily gives no trouble from spontaneous heating when stored, mainly because there is not enough surface area.

TABLE 1. - Variation of surface area of ton of coal with coal size (coal considered to be in the form of cubes or spheres of the size designated)

Size	Square feet per ton	Size, mesh	Square feet per ton
2.83-foot cube	48	4	8,727
6-inch lump	272	8	17,416
3-inch nut	544	16	34,796
1-1/2-inch	1,088	30	70,341
3/4-inch	2,176	50	139,479
3/8-inch	4,352	100	276,595

(5) Coals that slack in storage provide more surface area for oxidation.

(6) Many persons have found that coal stored wet gives more trouble than coal stored dry. Attempting to cool a coal pile with water frequently creates further hot spots. Changes in wetness affect the ventilation of the pile and also the heating activity of the pyrite. Schmidt of the Bureau of Mines has suggested in a report unpublished to date that the movement of water vapor through a coal pile, with any resulting condensation on the coal, could aggravate heating conditions. He calculates that condensation of the small amount of water required to increase the moisture content from, say, 3 percent of the weight of the coal to 4 percent is sufficient to raise the temperature of the coal over 30° F.

(7) Air moving through a pile of coal supplies oxygen for burning and also carries away heat. It may cause increased heating or increased cooling, depending upon the amount. When coal is piled by letting it drop, the larger lumps fall to the outside (see fig. 1).[8] Such a pile creates an ideal condition for spontaneous heating. If one spot heats, it will gradually heat the whole pile. There is always the chance that some spot will receive exactly the right ventilation so that the correct amount of oxygen is brought in and yet not enough heat is carried away, as illustrated in figure 2. There is much air movement on the outside edges, yet in the center the air can hardly penetrate. There is no ventilation at some spots and much at others. Naturally, somewhere in the pile will be a spot where there is just the right ventilation to produce a "hot" spot. Figure 3 shows such a spot at A.

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[8] Figures from Hood, O. P., Spontaneous Combustion of Coal: Bureau of Mines Inf. Circ. 7074, 1939, 5 pp.

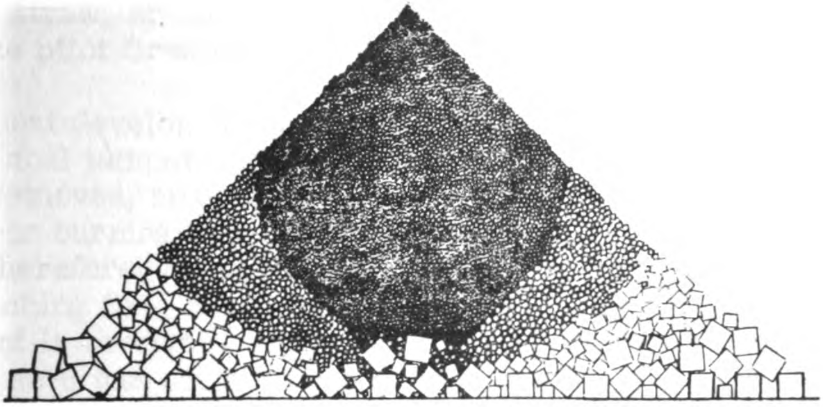

Figure 1.—Segregation of different sizes of coal in a conical pile.

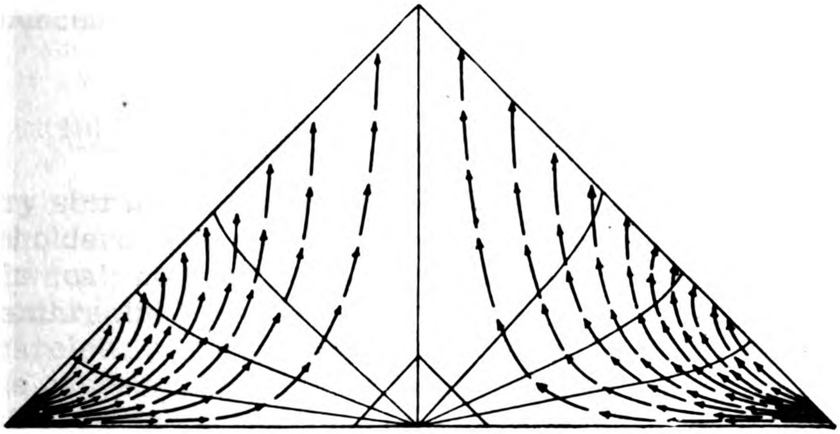

Figure 2.—Lines showing increasingly difficult paths for air circulation in a pile of coal.

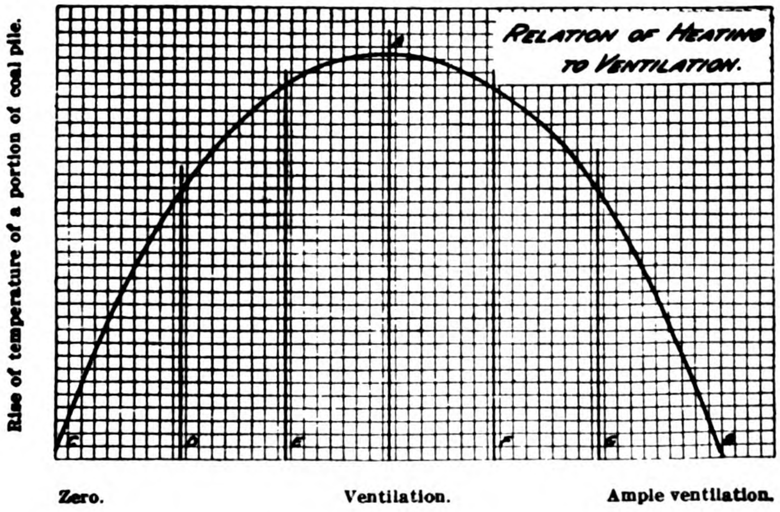

Figure 3.—Relation of heating to ventilation in a pile of coal.

(8) Foreign substances in the coal pile are always a hazard. Pieces of wood, straw, or oily rags not only affect the ventilation but frequently create pilot fires to start burning of the coal.

(9) If the heat developed spontaneously is removed as rapidly as it develops, the coal temperature will not rise. In a pile of coal where the heat is not removed, however, the temperature rises, and the rate of the oxidation or burning increases rapidly; it is self-aggravating. A pile of coal, therefore, might do anything from actually cooling to very rapidly catching fire, depending on how much heat is removed. The time element is involved. A pile of coal might stand 3 or 4 weeks without trouble, as it has not had time to heat, but later it might take fire.

(10) All sources of external heat should be avoided to the extent possible.

(e) Satisfactory Storage Methods

Satisfactory storage of anthracite does not present much of a problem. Householders need not expect to have spontaneous heating troubles with this coal; no occurrences of spontaneous heating of household-size anthracite have been found. Some difficulties have been experienced in careless storing of fine or buckwheat sizes in large, deep piles. Some causes of the trouble have been found to be foreign substances in the coal, an unusual amount of coal dust, and considerable heat from external sources. Under the necessary air-flow and temperature conditions, which rarely happen, anthracite will heat spontaneously.[9] The matter is still under investigation.

To assure absolutely that no undesirable heating will develop in any stored bituminous or subbituminous coal, it is necessary to use careful methods of storage that either prevent access of air to the coal entirely or provide for access of enough air throughout the pile to carry away the heat as rapidly as it develops. This latter is practicable only for sized coals. Different kinds of coal act quite differently in storage. It is not practical or economical for every plant to obtain the site and equipment needed to carry out methods that would satisfactorily store any and every coal. The problem for each plant is to select the most practical method that will give sufficiently satisfactory results for the kind of coal that is to be stored. Good judgment must be used, based on some knowledge of the causes of spontaneous heating and also on the results obtained for somewhat similar cases. A study is now being made of storage results throughout the United States under the many conditions of storage found in industry; from this it is hoped that information may be made available that will help in predicting the chances of heating for given storage conditions with given coals. To date, no difficulties with spontaneous heating of bituminous coals in the home have been found.

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[9] Scott, G. S., and Jones, G. W., Effect of Particle Size on the Rate of Oxidation of Anthracite: Bureau of Mines Rept. of Investigation 3546, 1941, 15 pp.

Methods of storage that may be considered include:

1. Storing coal under water. Desirable from a practical standpoint only under very special circumstances. Water prevents the access of air and hence all spontaneous heating. It does not harm the coal appreciably except to make it very wet, but this often is quite undesirable. If the very fine sizes are removed before underwater storage, the water will drain from the coal much better when the coal is taken from storage. Usually a cheaper and more satisfactory way of storing can be devised for most coals.

2. Storing in an open pit in the earth. This scheme is an offshoot of the water-storage method, arising from the attempt to avoid the use of water. The sides of the pit should be in good condition. Segregation of coal sizes should be avoided in placing the coal in the pit; it would be better to spread and compact the coal with a bulldozer tractor. The coal should not have a level higher than the top of the pit. Air has access to the top and to some little extent around the sides of the pit. Covering the coal with a layer of 10 or 12 inches of very fine coal would help to keep out the air. Coals that slack readily, such as subbituminous coals, will slack for some inches at the top. Whether or not undesirable heating will develop depends upon how the usual factors affecting spontaneous heating happen to act. This method certainly cuts down the possibilities of air flow and would afford satisfactory storage for many coals, including some of those more difficult to store. If much heating develops, the pit could be flooded with water. It is usually difficult to recover all of the coal in this method of storage.

3. Storing slack coal in layers 2 to 3 feet in thickness on hard or compacted earth or clay. This base must be free from all rubbish or vegetation. It should have reasonable drainage, but no special drainage schemes should be used, such as tile or an ash base that tend to permit access of

air into the bottom of the pile. If an ash base is used for drainage, it should be covered with a layer of hard clay to reduce air flow. Any segregation of coal sizes, any foreign material such as straw or sticks in the coal, and any external sources of heat should be avoided. The layers of coal should be compacted as with a caterpillar tractor, or even an ordinary truck run back and forth over the coal will help. A bulldozer blade mounted on a tractor can be used to level the layers. Compacting the coal can increase the amount of coal per cubic foot from, say, 15 to 25 percent. The sides of the pile ordinarily should have an incline of about 35° and be carefully compacted. Any reasonable height, say 15 to 50 feet, is practicable. This general method will store many eastern coals satisfactorily. Further precautions must be taken, however, for coals that fire more readily. A layer of fine coal dust over the pile helps to decrease air flow; a layer of nut-size coal on top of the dust will hold it down.

There are many general modifications to the above layer method that give satisfaction for many slack coals, particularly for the relatively smaller piles. Layering without compacting is used. Where slack coal is merely piled on open ground, letting the larger pieces segregate to the sides as it falls, trouble may well be expected unless the piles are very small. Such piles should not be over about 6 feet high. For higher piles, even for the best-storing coals, fires have started. The hot spots will start in the center and on the sides of the pile; a wind on the side of the pile will greatly increase the heating. If a trestle comes up through the pile, it provides an air channel that can soon develop heating.

There is a general belief that it is not best to store different coals together or to add new coal to old coal. Different slack coals have different size consists; a modified condition of ventilation is usually created at the joining area of two different coals that might be just right for heating conditions. This is particularly liable to happen when the coal is merely allowed to fall into storage with the usual size segregation; leveling the coal into layers breaks up this effect. New coal has a higher rate of oxidation activity than the same kind of old coal. On the other hand, the old coal may have had the needed time to have gotten well-started on heating. Different coals have different moisture contents that tend to cause a transfer of moisture. The entire question is one of how the fundamental factors happen to act. There have been countless examples of satisfactory storage where different coals have been stored together.

There is also a belief that if trouble is not experienced with a coal pile for about 90 days no difficulties will develop. Quite often this is true. The decreased rate of oxidation activity of the coal with time develops less heat. However, many other factors are involved in the temperature rise of coal; instances of undesirable heating have occurred 6 to 8 months after storage in piles that gave no particular difficulties up to that time. Coal stored in the early fall may not show appreciable heating until the hot summer months.

4. Capping coal pile with airtight coverings. Coal covered so that there is no air flow into and out of the pile cannot give heating troubles. Capping can even put out fires down in the pile. Some have merely covered the inclined sides of the pile. This sometimes will suffice, but it is not nearly as effective as covering the entire pile. Coverings that have been used (other than coal dust) include cut-back asphalts,[10] usually of the MC-1 and MC-2 grades, asphalt emulsion, and road tar RT-3 grade. These coverings also prevent coal-dust nuisance, windage loss, and moisture penetration.

Experiments by the author's division show asphalt emulsions to be a much better type of covering than the others. Asphalt emulsions having 40 percent water and also 25 percent water are on the market. There is little choice in these two asphalts for this purpose; however, the 40-percent-water material is somewhat easier to handle.

10/ Drewry, M. K., work cited in footnote 3.

The emulsion has the limitation that it might not set well at temperatures below, say, 25° F. owing to possible freezing of the water when it is applied on the pile. Where it is necessary to cover a pile at temperatures lower than 25° F., one of the other three materials mentioned could be considered; in general, however, it is not best to cap coal piles at these low temperatures unless absolutely necessary. A capping of asphalt emulsion is not so subject to cracking due to any settling or movement of the coal pile as are the other materials. When coal that has been capped with asphalt is reclaimed from storage, some care would have to be taken if the coal was to be used in pulverizers. Too much material of this type in any one place in the coal would gum up the pulverizer. Introduced into the furnace by fuel-burning equipment, the asphalt burns with the coal.

At present, these materials cost 6 to 12 cents a gallon. A gallon will treat about 1 to 2 square yards of surface to a thickness of 1/16 to 1/8 inch. For larger piles, this would be equivalent to about 0.1 to 0.2 gallon a ton. On the sides of a pile exposed to prevailing winds, a somewhat heavier coating could be used. The total cost for capping, per ton of coal, would vary with the shape of the pile or the relation of the square yards of area of the pile to the tonnage. It might range from a few cents up to 10 cents a ton. One 72,000-ton pile at Washington, D. C., was covered with asphalt emulsion at a total cost for labor and materials of about 2-1/2 cents a ton.

Special spraying equipment is available for capping purposes. These coverings are also readily applied by the ordinary road-spraying tank wagon used for spraying tar on roads. The material is heated in the tank wagon to about 125° to 150° F. and can be sprayed through the hand nozzle used on the edges of the road. The hose to this hand nozzle would require lengthening for the larger piles. In one instance a 150-foot hose was used; one man handled the nozzle to hand-spray the pile, retreating over the pile on the unsprayed coal. Another man moved the hose. Cracked capping can be patched in the same general manner. Any point on the pile can be reached by means of ladders to which boards have

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been nailed crosswise and by planks for walkways. Where equipment is available, the entire tank wagon can be swung over the pile, using the usual rear road spray. It is best, particularly for the larger piles, to spread and compact the coal with a tractor or similar means; this greatly decreases any tendency of the pile to settle and also decreases possible air movement through the pile. Large sheets of paper have been used in storage piles to stop the movement of air.[11]

Other capping materials tried have been portland cement, with coal dust for the aggregate, and even plaster of Paris.

Completely satisfactory information is not available as to the exact effect on heating in storage of coals sprayed with the usual oil or salt sprays. Apparently these do not increase troubles in any way and sometimes may be beneficial.

5. Storing in bins, bunkers, and silos. For best results with such storage, remove all foreign material such as sticks, and oily rags, avoid segregation of sizes and external sources of heat, and prevent the access of air. Usually the handling equipment for such storage appears designed to segregate sizes rather than prevent it. Many of the difficulties now being experienced in bins, bunkers, and silos could be lessened greatly if care were taken as to how the coal was spilled by the chutes. Another chronic trouble in present equipment is its inability to spill all the coal. There are corners or spaces in which old coal will remain until hand-shoveled, often causing heating difficulties (See p. 9). It is seldom realized what a relatively large amount of air can flow into the coal through small slits, cracks, or poorly closing gates. Some air usually flows up through a coal chute, having the ordinary cut-off, and on up into the bunker, whether or not the chute is full of coal. This applies particularly to high silos. Often air flow can be located with an ordinary candle flame. Most coals piled into a container really airtight on sides and bottom will not fire from air that reaches it only at the top. A layer of fine dust over the top is additional protection.

11/ Blast Furnace and Steel Plant, November 1941, p. 1135.

6. Storing sized coals. Sized coals with the fines removed give much less difficulty from heating. In such piles, the relatively small amount of coal surface develops only a small amount of heat, which can readily be dissipated. In general, the higher-rank coals with the fines screened out may be stored without difficulties from heating. An arbitrary lower size limit of 1/4-inch might be chosen. We have storage instances of washed Illinois 10-percent-moisture coals with a minimum size much less than this giving no trouble from heating. Conditions are changed somewhat if the sized coal slacks in storage, producing much fines.

7. Storage in the home. Spontaneous heating difficulties in the small piles usually stored in homes should not be expected with sized bituminous coals; no example of spontaneous heating has been found to date with slack bituminous coals. The ordinary precautions should be taken, however, to avoid foreign materials, sources of excessive heat, and appreciable size segregation. Slack-size coal should be leveled about every 18 inches as it goes into the bin. Six feet high for slack coals is a good limit. The pile may be examined at intervals to note any unusual conditions. For a coal that is considered hard to store, such as a low-rank or a subbituminous coal, added precautions should be taken. The bin should be made thoroughly airtight; slits or cracks in the bin should be closed and a removable partition should be built over the bin outlet or shoveling door. The coal should be leveled at the top. An airtight cover over the top could be considered for very high-moisture coals.

TEMPERATURE OBSERVATIONS

The temperature of a coal pile should be tested periodically with a thermometer or an equivalent scheme. This gives plenty of warning and ample time to avoid anything dangerous; it is only when the pile has been ignored that matters might get somewhat out of hand.

Lengths of ordinary gas pipe of about 3/4-inch size, closed at the bottom, reaching nearly to the base of the coal, may be placed about every 25 feet. A thermometer may be dropped down the pipe to explore for temperature. The pipe should not be removed once it has been inserted; this ordinarily leaves a little chimney in the coal, which facilitates heating.

If a temperature of about 120° F. is reached, the coal should be watched closely for any rapid rise in temperature. Plans should be completed so that the coal can be moved when desired or satisfactorily water-flooded. Sometimes the temperature will slowly rise to as high as about 160° F., then fall; at other times it will continue to active firing conditions.

Generally the coal must be moved when too much heating develops. The heated coal can be spread out to cool; often it is more convenient to use it at once.

Using water to put out a fire may be effective for the moment, but in many instances this only delays the necessity of moving the coal. If the equipment available permits thoroughly flooding the coal with water, the heating can be stopped. Generally, this flooding must be repeated at intervals. Spraying the top of the pile with water from a nozzle usually is ineffective; the water seldom gets down to the hot spot. It would be better to ram the nozzle down into the coal. Sometimes a mass of coke that the water cannot penetrate forms over the hot spot.

Improvement has been found in the use of the "water spear." The spear is made from pipe about 1 to 2 inches in diameter closed at the bottom in a sharp point. Side outlet holes are drilled into the pipe just above the point. At the other end of the pipe is a hose connection. A cross handle may be used at the top of the spear to aid manipulation. The spear is rammed down into the pile to the hot spot, facilitating water flooding.

Small storage fires have been put out by smothering with carbon dioxide gas. Either dry ice (frozen carbon dioxide) or the tanked liquid carbon dioxide may be used as a source of the gas. This method is based on the fact that if oxygen is prevented from reaching the coal the fire will go out. Use of carbon dioxide must be carefully planned and proper ingenuity used for satisfactory results.12/ The oxygen must be kept from the coal long enough for it to cool appreciably. Heating may redevelop after the carbon dioxide disappears. For some conditions, its use may provide a needed delay in the burning.

12/ Gutleben, Dan, Fighting Coal-Bunker Fires: Power. January 1942, p. 102.